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An analysis of the relationship between tactual and visual perception.

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AN ANALYSIS OF THE RELATIONSHIP BETWEEN TACTUAL AND VISUAL PERCEPTION[1]

by

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I. HISTORY

The history of psychology has harbored but few doubts regarding the qualitative specificity of sensations and the discreteness of sensations supposedly conditioned exclusively by different sense organs. Classifications of sensory modalities have been based altogether upon corresponding sense organs and sensory qualities. The result has been that the history of psychology is marked by much greater success in the process of reducing sensory consciousness into small sensory units, than in erecting a theory of how these same units become organized into a continuous, dynamic consciousness.

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Aristotle, in his *Sensus Communis,* made a mystical attempt to explain how sensory experiences regarded as discrete entities were utilized in a conscious whole. However, his doctrine of the ' common sense ' did not truly account for structural unity, and only provided a questionable functional whole in which the sensory parts were incorporated.

The doctrine of association lent itself well to the concept of the ' common sense ' with the result that it was not until the appearance of Hagen's work (1) that a plausible dissent was heard against the partite sensory composition of consciousness. Hagen suggested that the normal consciousness was visual and that all perceptions were made in terms of this modality.

The doctrine of local signs, of Lotze, and the methodology of Fechner, which was continued by Wundt, added a great superfluity of proof to the belief in discrete sensory qualities. It was not until the time of Pillsbury (2), Judd (3), Washburn (4) and Parrish (5) that any evidence to the contrary was produced. These four studies failed entirely by using different methods to separate visual processes from those of touch and kinaesthesis.

All during the nineteenth century cases of synaesthesia had been reported but since they were described and explained in the terms of associationism which assumed that the synaesthetic sensation was a secondary process accompanying the primary sensation, the validity of the primary sensation was not challenged.

Stratton (6), in his experiment on the effects of retinal inversion, found that the perceptions primarily of touch and kinaesthesis were inextricably bound up with those of vision. His results furnish more evidence than he himself saw. However, through his adherence to the doctrines of local sign and association, he was unable to make use of these valuable observations.

The unemphasized results of Stratton were confirmed in the work of Brown (7) and Wooster (8).

Benussi (9), in 1913, was able to demonstrate apparent movement in the field of touch. Later, Burtt (10) was able to verify Korte's laws in the tactual modality. Since then numerous studies have been made which emphasize different phases of apparent movement. In all of these instances the importance of visual processes for apparent movement can hardly be ignored.

Wheeler and Cutsforth (11) have shown that synaesthesia does not consist of a dual process in which the ' secondary sensory ' experience is an associative concomitant of the ' primary sensation '. The synaesthetic process is all that exists in the experience and without it no experience would be possible. The undifferentiated ' parent process ' is all that exists of the primary sensation and that does not even possess awareness of quality. It is merely a cognitive reference, a ' pretemporal ' awareness.

In 1920 Gelb and Goldstein (12) reported the case of a soldier suffering from a wound in the occipital region. The patient lacked visual memory and complex visual perceptions, and at the same time, failed to localize tactual experience when blindfolded, except as he made use of bodily movement.

In 1929, Förster (13) reported a study on mirror learning in which it was shown that motor learning depends on visual processes.

These studies, and many others, raise the question whether, after all, the orthodox conception of the sensory field, as one composed of discrete sense modalities, is correct. If the *Gestalt* theory is correct the orthodox conception is wrong, and a strikingly different view from that formerly prevailing must be held. The issue, specifically, is this: Do full-fledged perceptions develop independently in each modality, and are they to be explained in terms of sensory elements? It was in the interest of adding to the solution of this problem that the present study was undertaken of tactual-visual perception.

II. The Problem

The problem of whether the sensory field can legitimately be divided into discrete modalities such as visual, auditory, tactual, and so on, each qualitatively and functionally distinct from the other, is a problem of inter-modality relationships. The method by which it was attacked in this investigation consisted in general of requiring that a perception, supposedly originating and developing in one modality, be reproduced or duplicated in another. The two modalities selected were the visual and tactual-kinaesthetic, and the specific problem with which this study was concerned was the analysis and description of the mental processes involved in estimating size tactually and kinaesthetically and of reproducing that size visually. It was hoped that this procedure, which demanded a shift from one so-called sense modality to another, would furnish some cues regarding their dependence or lack of dependence. Means were adopted, as far as possible, of securing quantitative data of statistical reliability.

III. Preliminary Experiments

Prior to the adoption of the procedure finally employed, four preliminary methods and a total of fifty-one subjects were used. Although the preliminary studies produced quantities of positive material and furnished considerable insight into the nature of the problem it was necessary to abandon each, successively, due to some inherent defect within the method. All the preliminary methods employed concrete stimuli to be judged in relation to other concrete objects with the result that it was impossible to control the factor of learning a range or series of standards. This learning caused judgments to be rendered in terms of the entire series or in terms of previous judgments, and unnecessarily complicated the quantitative data.

IV. Apparatus

The apparatus used for the purpose of securing visual judgments of tactual size consisted of a semi-horizontal hand screen and a vertical board on the front of which was an adjustable diaphragm. (See Fig. 1.) The hand screen was made of one-half inch pine board ten by twenty-eight inches. It was mounted six inches above the end of a laboratory table upon two one-half inch pine boards ten by six inches. The front opening was

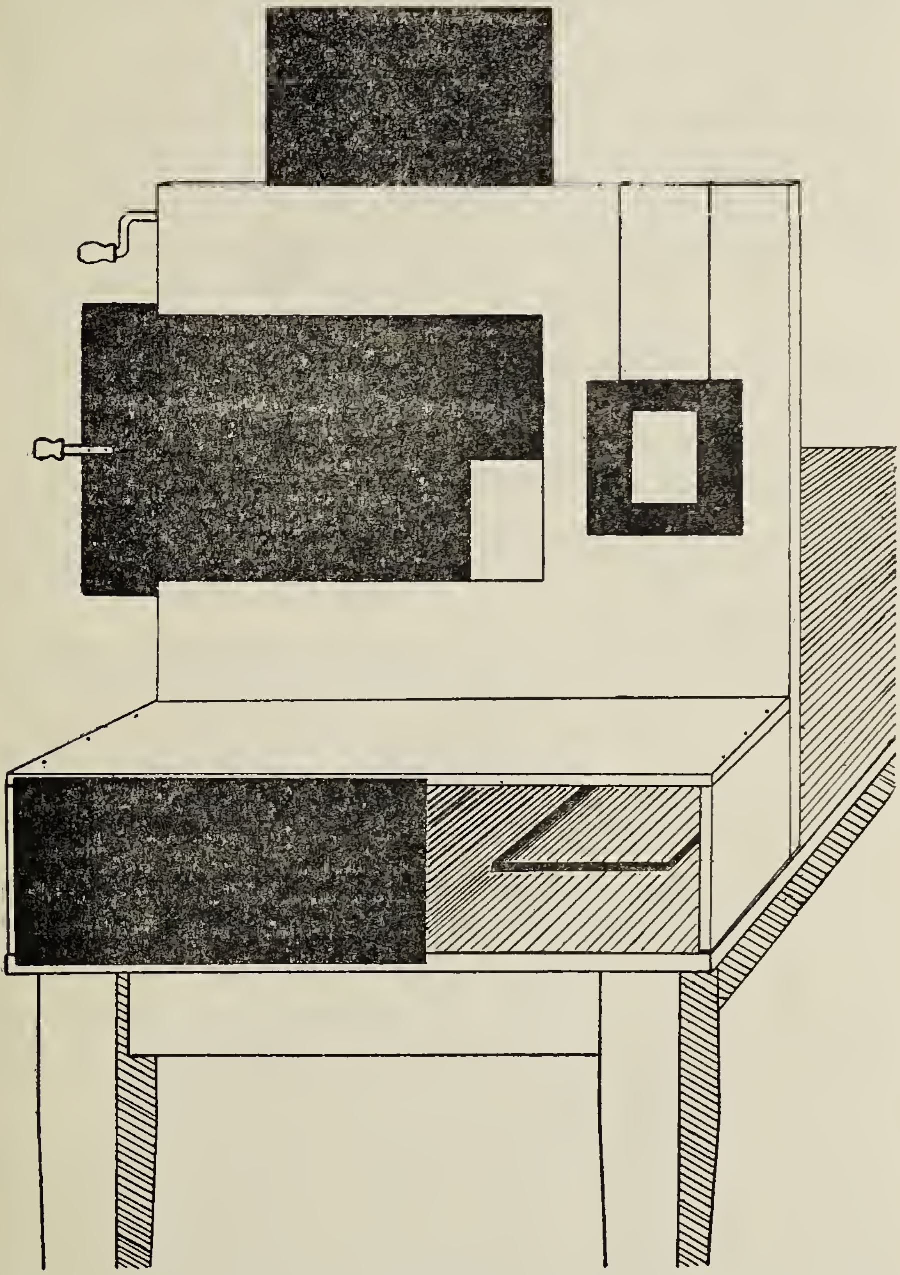

Fig. 1. Diagram of Apparatus to Show the Relation of Tactual and Visual Perception.

covered, with the exception of ten inches at the right, by a black cloth curtain hung from the edge of the screen. At the back edge of the board screen mounted on rods and clamped to the table, was the vertical board, one-half inch thick by twenty-eight by ten inches. Set out one-half inch from this vertical board was a black cardboard front with an aperture exposing a rectangle of white tagboard sixty by forty mm. Between the black front and back-board was inserted a sliding diaphragm which would shut off all the white background from the left. Also back of the black front, and in front of the sliding diaphragm, was inserted a black card-board diaphragm which shut off the aperture from the top down. The vertical diaphragm operated on a slide which was manipulated by the observer's left hand in trombone fashion. The diaphragm coming down from the top was mounted upon a sliding carriage, manipulated higher or lower by a crank, also at the left.

Attached to each diaphragm and extending through slots in the back-board were pointers which moved along millimeter scales. Readings could thus be taken off the scales by the experimenter behind the apparatus. The scales and experimenter were hidden from the observer.

Beneath the hand-screen, at the right end of the apparatus, was located a horizontal and vertical metal card-holder about three inches behind a hole in the screen through which the observer extended his hand. The card-holders held the tactual objects which the observer was to explore with his right hand hidden from view.

Five rectangular wooden figures were cut from one-half inch triple pine veneer in the following dimensions: No. 1, 120 x 80 mm.; No. 2, 90 x 60 mm.; No. 3, 60 x 40 mm.; No. 4, 45 x 30 mm.; No. 5, 30 x 20 mm. These blocks were mounted upon separate card-board squares six and one-half inches by six and one-half inches that slipped into the metal card-holders.

One white tagboard rectangle sixty by forty millimeters was mounted on a six-inch square of black cardboard to which were attached wire hooks so that it might be suspended from the top of the screen adjacent to the aperture previously described. The purpose of the visual rectangle will be described in the text.

V. MAIN EXPERIMENTS—METHOD

The investigation proper was divided into two parts. The first was performed with a group of ten trained observers made up of ten male members of the staff and graduates from the department of psychology. The second group consisted of 120 naïve observers—students from the elementary laboratory classes.

The experiment was performed in a dark room under the constant illumination of a one-hundred-watt incandescent lamp. The trained subjects made fifty-two judgments at each of six sittings held not less than seven days apart and not more than twenty-one days. The naïve group served as observers but once, during which sitting each made fifteen judgments.

The observer was seated in an ordinary chair in front of the apparatus with the adjustable diaphragm, so that it was convenient and comfortable for him to employ his right hand in the act of examining the tactual objects held in the card-holder, and at the same time manipulate the diaphragms with his left hand. His position brought the center of the diaphragm in the center of the field of vision. The observer was asked to examine the figure with his right hand tactually, and when he had perceived its size, to adjust the diaphragms until an area of white tagboard was exposed which duplicated the tactual figure. This procedure was employed with both the trained and naïve observers.

The trained observers were divided into two groups of five each. At the first sitting the members of the first group made two judgments which were purely visual. They were asked to reproduce upon the diaphragm the perceived size and form of a white piece of tagboard 60 by 40 mm., hung from the top of the apparatus just at the right of the aperture. One judgment was made at the beginning and the second at the end of the sitting. This was done for the purpose of checking the accuracy with the mechanical devices of the apparatus. In addition, these observers were asked to make 10 reproductions each of the tactual figures in the order as given, No. 1, 120 by 80 mm.; No. 2, 90 by 60 mm.; No. 3, 60 by 40 mm.; No. 4, 45 by 30 mm.; No. 5, 30 by 20 mm. During the first sitting of this group the figures were presented in a horizontal position with the long axes running north and south, map-wise. Also, at the first sitting, these observers perceived the tactual figure by the method of ‘ passive touch ’, that is, of placing the hand and fingers upon the figure without making exploratory movements. This will be called the Horizontal Passive procedure (H.P.).

In the second sitting of this group the observers were permitted exploratory movements of the index finger confined to the edge of the figure, the Horizontal Active (H.A.) procedure. On the third sitting the observer was permitted to employ any method of tactual-motor examination which suited him, the Horizontal Voluntary (H.V.) procedure.

On the fourth sitting the figure was changed to a vertical position with the long axis of the figure running up and down. On the fourth, fifth and sixth sittings the methods of tactual perception were repeated in order as in the horizontal position. These are to be called the Vertical Passive (V.P.), Vertical Active (V.A.), and Vertical Voluntary (V.V.) methods.

With the second group of five trained observers the procedure varied only in that the first sitting started the first of the vertical positions and the fourth started the first of the horizontal positions. Total judgments in all, by trained observers, 3,120, 50 judgments covering the 5 figures in each of 3 procedures, within two sets of positions of the figures. This number included the visual judgments.

The one hundred and twenty naïve subjects were divided into four groups of thirty. Each group made the two visual judgments as before, using the white visual rectangle; and each judged two series of five rectangles in one of the four methods, H.P., H.A., V.P., and V.A. Group one made their judgments with the tactual objects in a horizontal position employing the passive method of tactual perception (H.P.). The second group of thirty observers employed the horizontal position of the tactual object using active finger movement of the index finger about the edges of the figures (H.A.). The third group of thirty observers perceived their tactual figures in a vertical position by the static hand method (V.P.), and the fourth group of thirty observers also employed the vertical position of figures, but with exploratory movement of the index finger (V.A.). Total number of judgments by untrained observers, 2,040, 17 by each of 120 observers, 30 observers for each of the 4 methods used. Total number of judgments for the entire main experiment, 5,160.

VI. Results

1. *Judgments of Visual Size.* The ranges of judgments of height and width by both trained and untrained subjects demonstrate a surprising inaccuracy in matching one visual size with another visual size. The curves of distribution conclusively show the extent of inaccuracy in these judgments both for trained and untrained observers. The distribution of judgments for height, in case of the trained observers, extends from 55 to 67 mm., a scattering of 12 mm., or 20 per cent of the standard height. The mode occurs at 59 which is one point below standard height. The untrained observers scattered their judgments of height still further by extending the range from 50 to 68, a range of 30 per cent of the height. The judgments of height for the untrained observers form themselves into a bimodal distribution with the points of most frequent judgments falling at 56 and 60.

In the judgment of width, the trained observers scattered out over a smaller range running from 37 to 47, with a mode at 42. The range, which represents 25 per cent of the standard width, *falls for the most part above the standard.* The untrained observers scattered their judgments over a range, from 33 to 49, which is equal to 40 per cent of the standard width. The mode occurs at the same point as does the width of the standard but a larger part of the judgments fall below this point. An inspection of the curves shows that the trained observers are prone both in their judgments of height and width to over-judge the standard, and the untrained observers to under-judge the standard.

2. *The Discrepancy Between Sight and Touch.* A large discrepancy was found to exist between the tactually perceived standard and the matched visual equivalent in the judgments of all the subjects made in all the different positions, with all the differ-

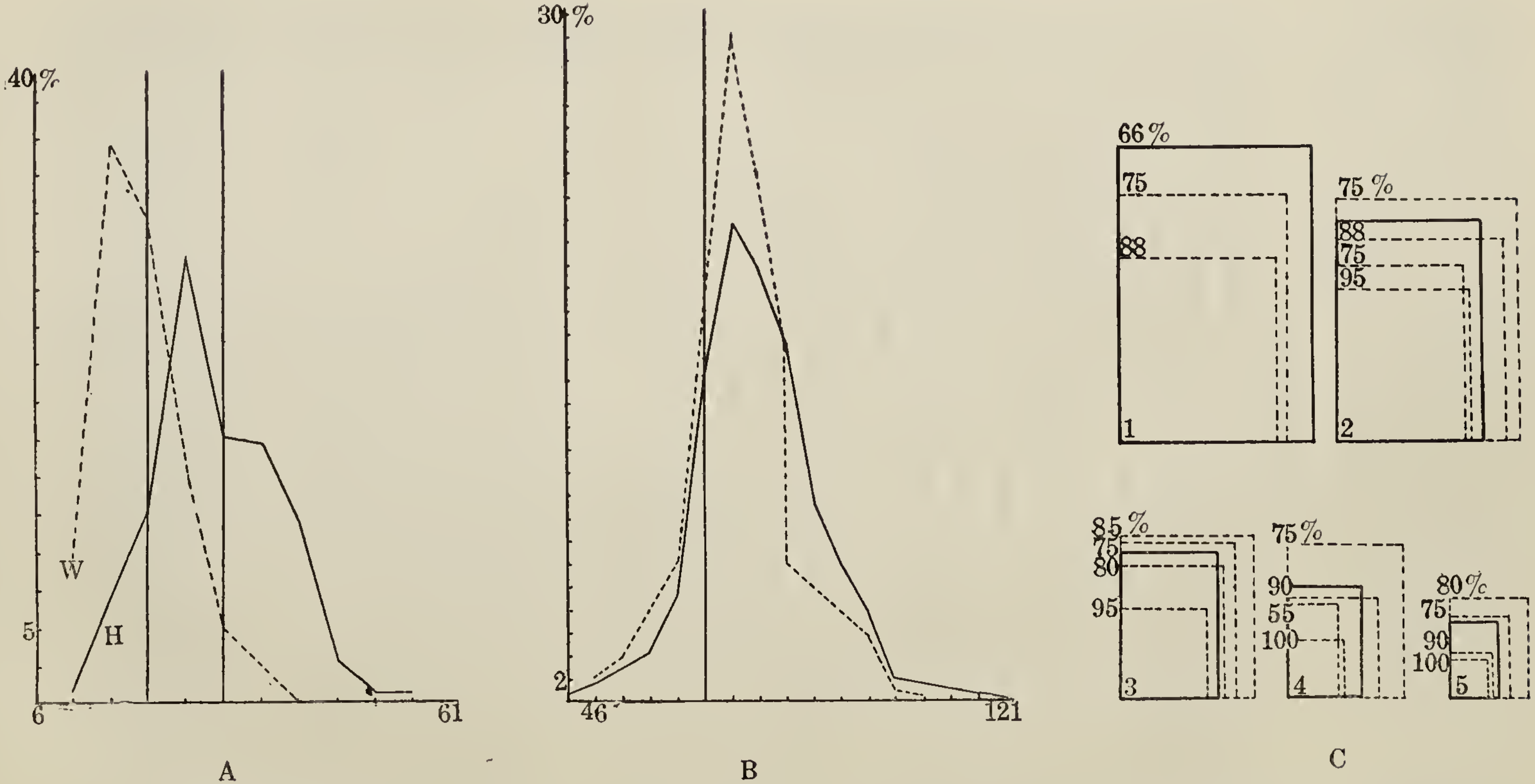

FIG. 2. A. Judgments by Per Cent. Block V. All Methods. W, Width; H, Height. Abscissa, Scale in Millimeters. Vertical Solid Lines Represent Dimensions of Block, 20 mm. and 30 mm. B. Distribution of Squaring Proportions. All Subjects and Methods. Solid Line, Untrained; Dashed Line, Trained. Abscissa, Arbitrary Scale. Solid Line Represents Ratio of W and H, Actual Stimuli. C. Squaring Judgments. Numbers, Per Cent of Squaring. Solid Lines, Actual Stimuli.

ent methods employed, and with all the five stimuli. Under-judgments of the tactual standard were made to the extent of 44 per cent of its size, and over-judgments of the standard ran to 47 per cent, with an average discrepancy running as high as plus or minus 12 per cent for certain of the stimuli. The ranges of distribution are modified by the different positions, methods and standards employed. (Fig. 2A shows underestimation of W and H.)

3. *The Effect of Position on the Discrepancy Between Sight and Touch.* The horizontal position is conducive to more accurate judgments than the vertical position. The different effects of the two positions can be seen from Tables II and III. Table III shows the discrepancies for height and width for the horizontal and vertical positions separately. These differences do not remain constant for all methods and all sizes, and also vary between observers. The difference between the horizontal and vertical positions and between trained and untrained observers is revealed not only in the two ranges of judgments which differ in extent, but also in the places along the distribution where the greatest number of judgments fall.

4. *Effect of Passive and Active Exploration on the Discrepancy Between Sight and Touch.* The two methods of examination of the tactual standards—passive, and active—produce different ranges of distributions of judgments. The effect of the two methods is displayed in Tables II and III. In Table III the extent of the discrepancy between the actual tactual standard and the matched visual size is given. The results show that the active method reduces the extent of over-judgments and increases the extent of under-judgments in both the height and width. That is, it shifts the range of distribution farther below the tactual standard. This effect becomes less apparent on the smaller blocks, and is less apparent for naïve than for trained observers.

The effect of movement upon tactual perception would indicate that tactual space was less apparent during movement than when the hand was in a passive state. The fact that the trained observers exaggerated this tendency as compared with the untrained observers would indicate that the trained observers possessed perceptual equivalents for a less amount of the finger movement than did the untrained observers. The trained observers, also, moved more slowly than the naïve.

It is not to be contended that it is possible to separate entirely the effects of the combined influences of position and movement. It can be seen that passive judgments made from a horizontal position are distinctly different from those passive judgments made in a vertical position. *But, each of the two conditions in combination produce relationships which neither can be held responsible for separately.*

5. *Influence of Size on Discrepancy Between Sight and Touch.* Size of block exerts an influence upon judgments of tactual size. (Table I.) The chief tendency is to over-judge the smaller sizes more than the larger sizes. This holds throughout for all the judgments by all subjects using the different positions and methods. The inter-relating effects of these conditions can be seen by an inspection of Fig. 2, C. Conversely, the large sizes are underestimated the most. Naïve observers are slightly less affected by difference in size than are the trained observers. It is interesting to note that the relative distortions of blocks two, three, and four are about the same, while the extremes, one and five, show the extreme distortions.

6. *Symmetry in Purely Visual Judgments.* There is a tendency to perceive visually, a vertical rectangular figure of the proportion of three to two in the more symmetrical relationship of a one to one proportion. The importance of this tendency is still more significant in actual perception of form and will be discussed separately in a special section. However, the suggestion may be made here that the perceptions of visual proportion and form-relationship not only include the perception of form but also the perception of *size* as well. *Size, of necessity, is a perceptual whole that cannot be constructed from separate judgments of height and width.*

7. *Symmetry in Tactual-Visual Perception.* A tendency toward symmetry was found in 78 per cent of all judgments made from tactual forms. Note that each stimulus-figure possessed the height-width ratio of 3 to 2. Therefore, when the

height has been reduced 66 per cent, the width remaining constant, a square has been produced. For the sake of convenience the number 66 was chosen to indicate the per cent of approximation to a square represented by a rectangle of 3–2 proportions; a perfect square being indicated by 100 per cent. Numbers below 66 indicate a lengthening and narrowing of the 3–2 proportions, respectively, while figures over 100 represent a shortening and widening of the figure beyond that of square proportions. The distribution ranges from 41 to 148 with 66 representing the standard proportion. (Table II.) The mode of the squaring tendency occurred between 71 and 76. Fig. 2B pictures the ranges of squaring graphically.

8. Effect of Passive and Active Methods on Symmetry. The two methods of tactual exploration of the standard had opposite effects upon the tendency toward symmetry. The untrained observers do less squaring when the form is perceived passively and increase the amount of squaring when movement is employed in making the perception. The trained observers do their greatest amount of squaring in the method of passive exploration and decrease the amount of squaring when movement is employed. This shows clearly that neither method possesses an effect inherent in itself but is associated inextricably with other factors. These results seem to hinge upon the fact that the trained observers were too analytical and lost their perception of proportion, especially when making slow exploratory movements.

9. Effect of Size on Symmetry. The trained observers tend to square the smaller figures more than the larger ones. Any extreme diminishes the squaring. Block three shows the greatest amount of squaring, which would indicate that block three received the combined effects of the trained and untrained. The opposite effects of size upon the two groups of observers would indicate that other and more subtle factors were operating than differences in actual size.

10. Relation of Squaring to Accuracy of Visual-Tactual Judgments. It may be concluded that those conditions which are conducive to accurate judgments of size are also conducive to squaring. These conditions are not constant throughout the entire investigation nor do they apply equally to both groups of observers. Already it has been shown that the observer himself is an important and neglected factor among the conditions under which the judgments are formed. The different positions, methods, and sizes of blocks cannot be regarded as separate and distinct conditions of judging as such, but only as separate conditions in relation to the observer's procedure.

The relation of the range of judgments of height and width to the actual height and width shows to what extent the figures are broken up and analyzed, especially by the trained observers. The discrepancies between these judgments and actual height and width of the three blocks, one, three, and five, show how the two factors of accuracy and squaring are related. In block one the average judged height is 74 per cent of actual height, width 94 per cent. In block three the average height is 120 per cent, and width 137 per cent. In block five the average height is 160 per cent, width, 150. In block three accuracy and squaring are at their maximum while in block one both accuracy and squaring are less. Finally, in block five both the accuracy and squaring are still less in virtue of a 50 per cent discrepancy in both height and width.

11. Differences Between Individuals and Groups in Squaring. The tendency toward squaring shows more consistency within individuals than it does between individuals. Like the judgments of size the individuals retained their own consistency under the different conditions although the actual amount of squaring was made greater or less owing to a given condition.

The range of all individuals from the least amount of squaring to the most squaring for all positions and for all blocks was 50.6. The greatest range of any individual in any position was 24.7. The least range was 1.9 for a given position. The least average range for the four methods was 4.7 and the greatest was 16.1. The average for all individuals was 10.0.

12. General Differences Between Trained and Naïve Observers. Visual Judgments. Throughout the presentation of the results there have appeared differences between the group of trained observers and the untrained group. The apparent differences between these two groups are difficult to describe in quantitative terms. In the following paragraph will be presented the differences between the two groups as shown by the experimental data. No attempt in this section will be made to interpret the differences.

In comparing the two visual forms untrained observers underestimate the standard while the trained observers showed the opposite tendency, that of overestimating the standard. These diverging tendencies were consistent for both height and width.

The trained observers tended to square the visual form more than the untrained observers. In their judgment of tactual standards the untrained observers are more consistent, as shown by higher modes in the curves of distribution. The trained observers give more exaggerated and frequent bimodal distributions.

13. Differential Effect of Position on Trained and Naïve Observers. Table I shows the effect of position upon the two groups of observers. It will be found that the vertical position favors an overestimation of both height and width by the trained observers, while the horizontal position favors overestimation in the untrained observers. The vertical position favors more underestimation of height and width by the trained group of observers although both groups do a great deal of underestimating. In other words, the trained observers do more underestimating in the horizontal position than do the untrained and the difference is increased in the vertical position. The untrained observers make more judgments toward squaring on both the horizontal and vertical positions. In the former position they are in excess of the trained group to the extent of seventy-one judgments and in the latter position to the extent of one hundred and fifty-two judgments.

14. Differential Effect of Method on Trained and Naïve Observers. The active method of exploration supports approximately twice as much squaring as does the passive method. The untrained group does more squaring in both methods than does the trained group, but the greater excess of squaring occurs under the passive method. This would indicate that the two methods have opposite effects on squaring in the two groups of observers.

15. Differential Effect of Size of Block Upon Trained and

Naïve Observers. The series of five blocks as a whole is underestimated much more by the trained subjects than by the untrained. As the blocks become progressively smaller this difference is increased. A similar trend is found between the two groups in the extent of squaring. The trained observers square the blocks less than the untrained and the difference becomes progressively greater as the blocks become smaller.

It would appear as if squaring and the range of distribution in relation to the standard form are closely related. In both the larger block and the smaller block there occurs a greater breadth in the distribution of judgments and also a less amount of squaring, hence it would seem that the extremes of size destroy both accuracy in judgment and at the same time the tendency toward symmetry. Throughout, the untrained observers are more accurate and make their visual figures more symmetrical. *This fact means that accuracy depends upon squaring, i.e., a perception of proportion, rather than upon an analytical judgment of discrete heights and widths.* The trained observers analyzed the tactual object into height and width, reproducing each separately, and therefore were less accurate than the naïve observer who perceived the tactual object more as a whole in its proportion and reproduced it as a whole.

VII. QUALITATIVE RESULTS FROM THE JUDGMENTS OF THE BLOCKS

The following are typical unsolicited comments made by observers while sitting for the experiment. " The tactual figure is not straight." " The apparatus isn't large enough to represent the block visually." " The block has an irregular form." " The angles of the block are not right angles." " The blocks appear to be diamond-shaped." " I cannot make the aperture fit the block."

The following are typical reports from trained observers. " The blocks all seem to be the same size with the exception of the small one." " The bigness is not controlled by the size of the block." " The blocks all seem like squares." " The judgment seems wrong but I can't do anything about it." " The blocks seemed awfully big but suddenly seemed to shrink on me." " The longer I explore it the smaller it becomes." "When comparing the tactual and the visual the tactual shrinks." "When I close my eyes the tactual lengthens." "When I open my eyes and look at the visual aperture, it swells." "The block gets smaller as I put my hand on it." "I don't see how I could possibly have made it so big."

These excerpts show definitely the dearth of criteria with which an observer can make a comparison between a tactually perceived object and a visual one. These criteria depend exclusively upon the fact that the tactual perception is as much visual as it is tactual. No observer could find a single tactual criterion as such enabling him to make his judgment. Hence the discrepancy between the actual sizes of the two figures, the tactual and the visual. The subject found it necessary to construct the tactual figure visually without seeing it before he could make a comparison between it and the actual visual figure.

The following conclusions can be drawn from the introspective data: (1) Tactual perceptions of form are distorted through lack of possible criteria of judgment. (2) Tactual perceptions of size lack definiteness for the same reason. (3) Both tactual form and size are recognized by the observers as being unreliable and without criteria. (4) Apparent movement takes place in tactual-visual perception.

VIII. Apparent Movement Between Tactual and Visual Figure

At the close of the sixth or last sitting each of the trained observers was given a test for tactual apparent movement. The procedure for this consisted in presenting block three in the horizontal position with the instructions previously given for the active method. He was told to examine the figure very carefully about the edges and to adjust the diaphragms so that the visual figure matched in size the perception of the block. When this was accomplished he was instructed, further, to fixate the visual figure in the diaphragm carefully and at the same time to place his hand upon the block in the manner of the passive method. After this was done the observer was asked to report how the two sizes of the same figure were reconciled, what the appearance was of the figure in the diaphragm and what the appearance was of the figure under the hand.

Three of the ten observers reported that all changes took place in visual imagery of the hand and of the block under the hand. Two of these three reported that the block under the hand appeared to become larger. One reported that he could *feel* the block get larger during the change, but this was a visual-tactual ' feeling '.

Five of the ten subjects were able to perceive an apparent movement upon the figure in the diaphragm. Also at times some of them would report an enlargement of the visualized block under the hand.

Two of the subjects were able to get no transitional changes in the perceptions of size. They were aware that change in size had occurred but they were not aware of anything until after it had happened.

The following are typical reports of the trained observers. " I visualized my finger movements as I stretched out my hand to place it over the block." " The changes are in the tactual figure visualized in the hand." "A definite visual shrinking took place in the block in my hand. It moved in on all sides at once." " On one side of the visual figure the movement takes place, both as a shortening and as a lengthening of the line. It occurs at the opposite end from that which is fixated. I can produce it on both the vertical and horizontal lines. I must get an actual equality of vividness between the tactual and visual perceptions of the squares before movement will occur." " The movement of the hand appears to correlate perfectly with the visual apparent movement. It functions when the visualized perception of the tactual square, or form, flits up to the visual form on the diaphragm. Then the tactual size is perceived in the apparent movement and when the tactual returns the visual form retracts to the visual size." " The change is very rapid and is not always perceived as movement, but merely as a change that has taken place." " While I am fixating the diaphragm I can see the tactual block shrink. It is projected upon the aperture with its sides coinciding with the sides of the aperture. The shrinking takes place upon the aperture." "When the tactual object is again perceived, the visual figure increases in size. It changes on all sides in a visual outward movement." "When I grasped the block it became larger. It was a visual swelling of the pressure-pattern in my hand." "With a passive grasp of the block and by shifting my hand-pressure lightly from one side to the other, I can see one side of the visual figure extend in both directions when I fixate the center of the side."

Masses of introspective data like the above may be summarized in the following fashion: (1) Apparent movement may take place on either the tactual or the visual figure as an effort is made to correct a discrepancy between the two perceptions of size. (2) Ordinarily apparent movement involves the shrinking or swelling of the whole figure. (3) With an analytical attitude apparent movement may involve but a single side of the visual figure. (4) Under an analytical attitude the movement may be perceived in a single side, as moving in either direction or as moving in both directions when the side is fixated in the middle. (5) The movement may occur in the form of concrete visual imagery or in highly schematized visual imagery. (6) Under the conditions of this experiment tactual processes as such do not yield apparent movement. The movement is seen, not felt. (7) At no time was an observer, naïve or trained, able to describe tactual form or size in other than visual terms.

IX. Discussion

Since it is possible to demonstrate that touch is incapable of supporting spatial perceptions of size and form, it is necessary to harmonize these findings with theoretical views which may account for such a flagrant violation of the constancy hypothesis. Were it any longer possible to think in terms of specific sensory functions, the condition which we found in our experiment might be described as visual processes having usurped the perceptual functions carried by touch. Any such explanation as this is quite inadequate to describe the total visual nature of tactual experiences in our subjects.

It is necessary to regard the judgments of our subjects genetically and ask the question if touch has ever been a factor in the tactual perception of spatial size and form. In the development of the infant, visual perceptions in the case of normal eyesight always precede that of spatial tactual perceptions. In other words, spatial relationships at the very first become differentiated and emerge from a visual ground. The space frame of the normal seeing child is what might be described as a synaesthetic visual space frame out of which spatial relationships must be structured. The extent to which the visual ground may be spatially differentiated has not yet been determined, but it has been found that it is sufficient to support so-called tactual apparent movement which was employed by our subjects in relating discrepancies in tactual-visual space.

The congenitally blind, who have never maturated in a visual direction, possess a kinaesthetic ground out of which spatial relationships differentiate. It by necessity carries a much higher subjective or bodily relationship to spatial perceptions than the more objective visual spatial relationships. The extent to which these two spatial grounds are employed in the total spatial perceptions of the normal seeing is as yet undetermined.

The results of this investigation are in agreement with those of Gelb and Goldstein as regards the importance of the visual field for tactual perception.

In general the results are in accord with a *Gestalt* conception of the sensory field which presumes that the field is a functional unit, not an aggregation of discrete modalities. They compel the assumption that the genetically simplest type of consciousness is an organized whole, undifferentiated with respect to quality, and that, qualitatively, there must be a common ground like the visual or the kinaesthetic upon which and partly in terms of which all figures, involving size, position and form, must exist. And finally, they are not in accord with the assumptions of association psychology that the sensory consciousness is composed of parts or elements which blend and fuse *into* a whole. They point to the assumption that the qualitative aspects of sensory consciousness are derived through processes of differentiation that follow organismic rather than mechanistic laws.

X. Conclusions

1. Under all our experimental conditions discrepancies occur between the 'tactual' perception of size and the visual perception of the same size.

2. The discrepancy between 'tactual' and visual perceptions of the same form occur in all individuals, with the different forms and sizes of standards and under all methods and positions employed in the investigation.

A. Within individuals the extent of the discrepancy may amount to a plus or minus 47 per cent of the standard.

B. Within a group the average discrepancy may amount to a plus or minus 12 per cent of the standard.

3. The extent of the discrepancy occurring between 'tactual' and visual perceptions of the same size is greater for the trained subjects than for the untrained.

A. The difference between the two groups is due to the more analytical attitude of the trained subjects who employed more discrete and isolated criteria in forming their judgments, and attempted to construct a whole from its parts.

4. The discrepancy between the two perceptions of the same size was greater when the active method was employed than with the passive.

A. The active method of tactual exploration favors a more analytical perception of form, by emphasizing the discreteness of height and width.

B. The passive method of exploration favors a tactual perception of the form as a whole in which both height and width are included not as discrete aspects but as a proportion.

5. The discrepancy between 'tactual' perceptions of size and visual perceptions of the same size is greater when the 'tactual' perception is made with the object in a vertical position than when it is made in a horizontal position.

A. Vertical 'tactual' perceptions are made with less manual facility and dexterity. The perception is less homogeneous and the criteria for making the judgment are less reliable.

6. Discrepancies between the perception of 'tactual' size and visual perception of the same size are greater when the standards are extremely large or extremely small.

A. Objects whose size is convenient for manual exploration lend themselves to more accurate perceptions of ' tactual ' size.

7. Although underestimation and overestimation of both height and width do occur, underestimations of both height and width are the usual type of discrepancy.

8. The underestimation of height occurs more often than the underestimation of width.

9. In the act of matching a visual form to a tactual rectangle, a figure more closely approaching a square is usually produced.

10. In the act of matching a visual form to a visual rectangle, a figure more closely approaching a square is produced.

A. The squaring usually takes place in the direction of underestimating the height and either underestimation of width to a less extent or an overestimation of width.

B. Sometimes the squaring is produced by an overestimation of both height and width in the proper proportion.

11. Similar squaring processes occur in both the visual and ' tactual ' perceptions of rectangular form. There is a disposition to perceive the figure squarer than it is.

12. The ' tactual ' perception of proportion is the most reliable basis upon which to construct a visual equivalent.

A. Greater inaccuracy occurs when less usable criteria are employed.

13. The ' tactual ' perception of *size* and *form* is exclusively a visual configuration.

14. No truly tactual patterns were found in the ' tactual ' perceptions of form.

15. A. The perceptions of ' tactual ' form were carried in visual imagery.

B. Tactual qualities provide ' texture ', ' body ', and subjective reference but form, extent, position and organization are visual.

16. Apparent movement occurs when the discrepancy between the ' tactual ' and visual perceptions is noted. Then the movement seemingly occurs in the line of least action as a process of equilibration whereby one of the perceptions is corrected to the other. This does not, however, eliminate the error.

17. Apparent movement, under these conditions, is a visual adjustment made to two visual extents previously perceived in an erroneous fashion as equal.

18. This apparent movement differs in kind with different observers.

A. Concrete apparent movement occurs in those individuals who perceive movement in their concrete visual imagery. Schematic apparent movement occurs in those individuals who are able to perceive the movement as divorced both from concrete objects and from the body.

19. Apparent movement in its various forms and varieties is always visual under the conditions of our experiment.

20. The exclusively visual nature of apparent movement confirms the fact that ‘ tactual ’ patterns do not, as such, exist.

21. The continuity and uniformity of experience, as revealed in this investigation, necessitate the field-concept of sensation, in which one sensory organization serves for all modalities.

22. Throughout our investigation no evidence could be found that a sensory configuration of homogeneous quality (tactual) was organized upon the ground of another and different sensory quality.

23. Visual imagery furnishes continuity between otherwise discrete tactual features of complex ‘ tactual ’ perceptions, such as varying intensities and qualities at different places on the skin.

A. Visual imagery furnishes continuity between tactual figure and conscious ground. The ground of ‘ tactual ’ perception is visual.

24. The tactual experiences of our observers reveal, without exception, the phenomenon of synaesthesia.

25. Within the limits of our investigation, ‘ tactual ’ perceptions are always visual-tactual. It is evident that in the genetic development of these perceptions, in seeing individuals, maturation and specialization take place in visual processes, not in tactual.

That is, the form, localization, extent, movement, and qualitative differentiation found in so-called 'tactual' perceptions are fundamentally visual.

A. This fact is consistent with the modern trend in psychology to dispense with a systematic differentiation between visual sensation and visual imagery.

26. From the results of this experiment it is necessary to conclude that the tactual field does not function, in seeing individuals, separately from the visual. The two modalities are not, and cannot, be distinct for the purposes of perception. It is an error to speak of a pure tactual or tactual-motor perception.

XI. Appendix of Tables

TABLE I

Overestimations and underestimations—Number of cases out of sixty

	Block 1		Block 2		Block 3		Block 4		Block 5	
	Tr.	Naïve	Tr.	Naïve	Tr.	Naïve	Tr.	Naïve	Tr.	Naïve
Overestimations of Height and Width										
H.P.	14	12	14	12	22	19	23	23	24	22
H.A.	1	20	14	23	19	28	19	27	26	35
V.P.	21	10	28	10	21	10	19	19	14	29
V.A.	6	5	11	9	18	19	16	20	16	25
Total H.	15	32	28	35	41	47	42	50	50	57
Total V.	27	15	39	19	39	29	35	39	30	54
Total P.	35	22	42	22	43	29	42	42	38	51
Total A.	7	25	25	32	37	45	35	47	39	60
Total All	42	47	67	54	80	76	77	89	80	111
Underestimations of Height and Width										
H.P.	42	27	28	27	27	26	27	12	20	24
H.A.	35	25	29	18	36	13	37	10	26	8
V.P.	30	26	25	25	37	22	37	15	38	14
V.A.	36	28	44	29	41	22	48	15	37	10
Total H.	79	52	57	45	63	39	64	22	56	32
Total V.	66	54	69	54	78	44	85	30	75	24
Total P.	72	53	53	52	64	48	64	27	68	38
Total A.	71	53	73	47	78	35	85	25	63	18
Total All	143	106	126	99	141	83	149	52	131	56
Underestimations of Height and Overestimations of Width										
H.P.	5	17	17	19	10	14	10	22	3	13
H.A.	24	15	15	18	5	19	5	22	7	13
V.P.	9	24	4	23	4	26	3	25	1	17
V.A.	19	26	14	21	6	19	8	23	6	18
Total H.	29	32	32	27	15	33	15	44	10	26
Total V.	26	50	16	44	10	45	11	48	7	35
Total P.	14	41	21	42	14	40	13	47	4	30
Total A	43	41	29	39	11	38	11	45	13	31
Total All	57	82	50	61	25	78	26	92	17	61

TABLE I (*Continued*)

	Block 1		Block 2		Block 3		Block 4		Block 5	
	Tr.	Naïve	Tr.	Naïve	Tr.	Naïve	Tr.	Naïve	Tr.	Naïve
Overestimations of Height and Underestimations of Width										
H.P.	0	3	0	2	0	1	1	3	2	1
H.A.	0	0	0	1	0	0	0	1	1	4
V.P.	0	0	0	2	0	2	1	1	6	0
V.A.	0	1	0	2	0	0	0	2	5	7
Total H.	0	3	0	3	0	1	1	4	3	5
Total V.	0	1	0	4	0	2	0	3	11	7
Total P.	0	3	0	4	0	3	2	4	8	1
Total A.	0	1	0	3	0	0	0	3	6	11
Total All	0	4	0	7	0	3	2	7	14	12
Totals										
Over H. & W.	42	47	67	54	80	76	77	89	80	111
Under H. & W.	143	106	126	99	141	81	149	52	131	56
U.H.O.W.	57	82	50	61	25	78	26	92	17	61
O.H.U.W.	0	4	0	7	0	3	2	7	14	12
Naïve and Trained Combined										
Over H. & W.	89		121		150		166		191	
Under H. & W.	249		225		222		201		187	
U.H.O.W.	139		111		103		128		78	
O.H.U.W.	4		7		3		9		26	

Total cases 1,200, 60 judgments of each block in each position or method.

TABLE II

Median squaring trained subjects

	Block 1		Block 2		Block 3		Block 4		Block 5	
	H	W	H	W	H	W	H	W	H	W
Subject R.K.										
H.P.	77.5	95.6	89.3	103.0	109.0	114.0	120.0	122.0	143.0	130.0
V.P.	100.0	114.0	112.0	129.0	117.0	116.0	132.0	123.0	122.0	100.0
H.A.	97.5	115.0	110.0	126.0	113.0	125.0	137.0	130.0	147.0	130.0
V.A.	100.0	116.0	111.0	131.0	129.0	124.0	136.0	122.0	120.0	102.0
Subject C.W.										
H.P.	99.6	108.0	95.0	102.0	95.9	98.2	94.4	95.0	93.0	100.0
V.P.	82.1	92.5	78.3	90.0	81.7	90.0	76.7	80.0	86.7	90.0
H.A.	90.0	115.0	80.0	93.0	90.8	96.5	88.9	95.0	105.0	108.0
V.A.	91.7	109.0	80.0	95.0	77.5	83.8	77.9	96.7	93.3	98.5
Subject T.P.										
H.P.	82.5	94.4	91.1	107.0	85.0	95.0	91.1	103.0	86.7	95.0
V.P.	79.6	89.0	90.0	100.0	80.8	85.0	80.0	86.7	86.7	92.5
H.A.	80.8	89.4	95.6	104.0	72.4	82.5	97.3	81.7	85.0	103.0
V.A.	75.4	85.0	90.0	100.0	82.5	88.9	82.2	86.7	93.0	100.0
Subject W.W.										
H.P.	72.9	80.6	73.9	85.0	88.2	101.0	105.0	118.0	98.3	120.0
V.P.	99.6	89.4	86.1	96.7	85.8	98.7	91.1	107.0	102.0	110.0
H.A.	61.7	72.5	69.9	82.5	78.3	95.0	87.8	107.0	98.3	122.0
V.A.	62.5	71.9	80.0	86.7	106.0	104.0	120.0	112.0	147.0	140.0

TABLE II (*Continued*)

	Block 1		Block 2		Block 3		Block 4		Block 5	
	H	W	H	W	H	W	H	W	H	W
Subject M.R.										
H.P.	77.5	87.5	75.5	83.3	80.0	82.2	73.3	71.7	76.7	65.0
V.P.	91.7	100.0	81.7	84.4	87.5	86.2	88.9	75.0	102.0	70.0
H.A.	91.2	103.0	92.2	107.0	101.0	100.0	104.0	96.7	113.0	97.5
V.A.	103.0	105.0	88.9	95.0	97.5	96.2	97.8	96.7	120.0	80.0
Subject E.N.										
H.P.	103.0	98.7	112.0	110.0	110.0	111.0	116.0	122.0	137.0	125.0
V.P.	88.5	95.0	106.0	108.0	102.0	102.0	110.0	103.0	113.0	105.0
H.A.	107.0	108.0	120.0	117.0	113.0	117.0	110.0	113.0	123.0	115.0
V.A.	102.0	100.0	119.0	111.0	115.0	105.0	112.0	107.0	137.0	113.0
Subject K.S.										
H.P.	84.2	87.5	93.9	103.0	98.8	119.0	108.0	132.0	128.0	152.0
V.P.	85.8	88.1	91.1	96.7	91.7	107.0	95.6	108.0	93.3	105.0
H.A.	82.5	90.6	83.3	99.1	98.8	120.0	100.0	120.0	115.0	135.0
V.A.	63.3	73.1	71.7	83.3	72.5	90.1	34.4	100.0	90.0	112.0
Subject R.W.										
H.P.	83.3	95.0	90.0	100.0	83.3	96.2	82.2	98.3	80.0	90.0
V.P.	103.0	95.0	103.0	117.0	85.9	97.5	85.7	96.7	90.0	87.5
H.A.	57.9	70.0	52.2	68.3	50.0	67.5	51.1	70.0	55.0	80.0
V.A.	70.0	85.0	55.9	73.3	48.3	67.5	70.7	110.0	55.0	82.5
Subject D.P.										
H.P.	77.5	85.0	83.9	95.0	89.1	95.0	88.9	91.6	102.0	100.0
V.P.	56.3	78.7	57.2	79.2	56.7	75.5	51.1	71.7	61.7	85.0
H.A.	75.8	83.6	75.0	85.0	70.0	72.5	67.8	75.0	80.0	80.0
V.A.	67.2	75.0	73.9	79.2	77.5	70.0	83.3	67.3	88.3	65.0
Subject H.B.										
H.P.	113.0	129.0	128.0	147.0	143.0	160.0	140.0	158.0	133.0	157.0
V.P.	117.0	139.0	117.0	141.0	136.0	159.0	133.0	155.0	147.0	190.0
H.A.	94.2	101.0	104.0	114.0	124.0	134.0	117.0	127.0	138.0	140.0
V.A.	90.8	96.2	90.0	104.0	95.9	115.0	100.0	120.0	115.0	130.0

TABLE III

Overestimations and underestimations; trained relative to naïve; per cents

	Block 1		Block 2		Block 3		Block 4		Block 5	
	H	W	H	W	H	W	H	W	H	W
All Subjects, Positions and Blocks										
H.P.Tr.	—13.7	—3.7	—6.7	4.0	—1.8	7.0	2.0	11.0	7.8	13.4
N.	—5.0	1.0	—7.0	1.0	—5.0	5.0	—5.0	10.0	0.0	15.0
V.P.Tr.	—9.5	—1.9	—7.8	4.0	—7.3	2.0	—6.5	.7	.5	13.6
N.	—10.0	3.0	—12.0	3.0	—9.0	5.0	—5.0	10.0	0.0	10.0
H.A.Tr.	—16.0	—5.1	—10.8	—.4	—8.9	1.0	—3.9	1.6	5.9	11.1
N.	—7.0	3.0	—5.0	8.0	—1.0	17.0	4.0	20.0	10.0	20.0
V.A.Tr.	—17.5	—9.4	—13.9	—4.1	—9.7	—5.5	—3.6	1.9	5.8	2.4
N.	—17.0	2.0	—16.0	1.0	—7.0	12.0	—5.0	16.0	3.0	15.0
Av.Tr.	—14.2	—5.0	—9.8	.9	—6.9	1.1	—3.0	3.8	5.0	10.1
Diff.Tr.	9.2		8.9		8.0		6.8		5.1	

TABLE III (*Continued*)

	Block 1		Block 2		Block 3		Block 4		Block 5	
	H	W	H	W	H	W	H	W	H	W
					Passive Method					
Trained	—11.6	—2.8	—7.3	4.0	—5.0	4.0	—2.2	5.9	4.1	13.5
Diff.	8.8		11.3		9.0		8.1		9.4	
Naïve	—7.5	2.0	—9.5	2.0	—7.0	5.0	—5.0	10.0	0.0	12.5
Diff.	9.5		11.5		12.0		15.0		12.5	
					Active Method					
Trained	—16.7	—7.2	—12.4	—2.2	—9.3	—2.3	—3.7	1.8	5.8	6.8
Diff.	9.5		10.2		7.0		5.5		1.0	
Naïve	—12.0	2.5	—10.5	4.5	—4.0	14.5	—5.0	19.0	6.5	18.0
Diff.	14.5		14.5		19.5		18.5		11.5	
					Horizontal Position					
Trained	—14.8	—4.4	—8.7	1.8	—5.3	4.0	—.9	6.3	6.8	11.8
Diff.	10.4		10.5		9.3		7.2		5.0	
Naïve	—6.0	2.0	—6.0	4.5	—3.0	11.0	—.5	15.0	5.0	17.0
Diff.	8.0		10.5		14.0		15.5		12.0	
					Vertical Position					
Trained	—13.5	—5.7	—10.8	—.05	—9.0	—1.7	—5.0	1.3	3.1	8.0
Diff.	7.8		10.3		7.3		6.3		5.0	
Naïve	—13.0	2.5	—14.0	2.0	—8.0	9.0	—5.0	13.0	1.5	12.5
Diff.	15.5		16.0		17.0		18.0		11.0	
					All Positions and Methods Combined					
Trained	—14.4	—5.0	—9.8	.9	—6.9	1.1	—3.0	4.0	5.0	10.1
Diff.	9.4		10.7		8.0		7.0		5.1	
Naïve	—9.7	2.2	—10.0	3.2	—5.5	9.7	—2.7	14.0	3.2	15.0
Diff.	11.9		13.2		15.2		16.7		11.8	
					All Subjects Combined					
Tr. & N.	—12.1	—1.6	—9.9	1.1	—6.2	5.4	—2.4	8.9	4.1	12.5
Diff.	10.5		11.0		11.6		11.3		8.4	

(For example, —13.7, the first figure in column one, means that trained subjects underestimate height in the horizontal passive method 13.7 per cent. The first figure in column two means that trained subjects underestimate width of Block No. 1 3.7 per cent in the horizontal passive method.)

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